IEEE Std 404-2000
(Revision of
IEEE Std 404-1993)

IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500 000 V

Sponsor

Insulated Conductors Committee
of the
IEEE Power Engineering Society

Approved 21 September 2000

IEEE-SA Standards Board

Abstract: This standard establishes electrical ratings and test requirements of cable joints used with extruded and laminated dielectric shielded cable rated in preferred voltage steps from 2500 V to 500 000 V. It also defines a variety of common joint constructions. This standard is designed to provide uniform testing procedures that can be used by manufacturers and users to evaluate the ability of underground power cable joints to perform reliably in service.
Keywords: cable joints, dielectric integrity tests, extruded dielectric cable, impulse withstand voltage (BIL), laminated dielectric cable, sheath/shield sectionalizers, transition joints, withstand voltage

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Introduction

(This introduction is not part of IEEE Std 404-2000, IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500 000 V.)

This revision of IEEE Std 404-1993 now includes a test protocol for joints used on extruded dielectric cables rated 161 000 V to 500 000 V with a corresponding change in the title of the standard. In addition, this latest revision has adopted the ac voltage design levels specified in the international standards IEC 60502-4 and IEC 60840 for the "high voltage time test."

Future revisions of this standard will address the increasing interest in extruded dielectric cable systems with reduced insulation wall thicknesses and with temperature ratings of 105 °C (normal operation)/140 °C (emergency operation).

The work of preparing this standard was carried out by Task Force B2W (formerly Group 10-27 of the Accessories Subcommittee #10) of the Insulated Conductors Committee of the IEEE Power Engineering Society. At the time this standard was approved, the task force had the following membership:

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IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500 000 V

1. Scope

This standard establishes electrical ratings and test requirements of cable joints used with extruded and laminated dielectric shielded cables rated in preferred voltage steps from 2500 V to 500 000 V. It also defines a variety of common joint constructions.

Joints that connect more than two cables or connect cables with two different conductor sizes are not covered by this standard. However, manufacturers and users are encouraged to use appropriate parts of this standard to evaluate these joints.

2. References

This standard shall be used in conjunction with the following references.

AEIC CS1-90, Specifications for Impregnated-Paper-Insulated Metallic Sheathed Cable, Solid Type (Withdrawn).[1]

AEIC CS2-97, Specification for Impregnated Paper and Laminated Paper Polypropylene Insulated Cable, High-Pressure-Pipe Type.

AEIC CS3-90, Specifications for Impregnated-Paper-Insulated Metallic Sheathed Cable, Low Pressure Gas-Filled Type.

AEIC CS4-93, Specifications for Impregnated-Paper-Insulated Low and Medium Pressure Self-Contained Liquid Filled Cable.

AEIC CS5-94, Specifications for Cross-linked Polyethylene Insulated Shielded Power Cables Rated 5 Through 46 kV.

[1]AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P.O. Box 2641, Birmingham, AL 35291-0992, USA (http://www.aeic.org/). AEIC publications are also available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112-5704, USA (http://global.ihs.com/).

AEIC CS6-96, Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 Through 69 kV.

AEIC CS7-93, Specifications for Crosslinked Polyethylene Insulated Shielded Power Cables Rated 69 Through 138 kV.

ANSI C119.4-1991, Electric Connectors—Connectors for Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Connectors.[2]

ICEA P-32-382 (1999), Short-Circuit Characteristics of Insulated Cable.[3]

IEEE Std 4-1995, IEEE Standard Techniques for High Voltage Testing.[4]

IEEE Std 82-1994, IEEE Test Procedure for Impulse Voltage Tests on Insulated Conductors.

IEEE Std 592-1990(R1996), IEEE Standard for Exposed Semiconducting Shields on High-Voltage Joints and Separable Insulated Connectors.

IEEE Std C37.09-1979 (Reaff 1988), IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

NEMA WC4-1988/ICEA S-65-375, Varnished-Cloth-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.[5]

3. Definitions

The following definitions are provided to describe terms used in this standard. They may or may not conform to other definitions used to describe cable joints. For definitions of other terms used in this standard, see IEEE 100, The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition [B5].[6]

3.1 Cable joint types

Cable joints are generally described by one of the categories that follow. These descriptive categories are provided only for convenience. They are not intended to cover all possible joint constructions. Some joint constructions may incorporate characteristics of two or more of the design types listed.

3.1.1 extruded: A joint in which both cables are insulated with extruded dielectric materials rated 2.5 kV to 500 kV.

3.1.2 laminated: A joint in which both cables have a dielectric that consists of fluid-impregnated paper or paper/synthetic laminated tape, or varnished cloth.

3.1.3 transition: A joint that connects an extruded dielectric cable to a laminated dielectric cable.

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[2]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/).
[3]ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (http://www.icea.org/).
[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[5]NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).
[6]The numbers in brackets correspond to those in the Bibliography in Annex A.

3.2 Cable joint constructions

3.2.1 cold shrink: A joint that consists of a tube or a series of tubes that are applied over the conductor and reduced in diameter over the cable without the use of heat.

3.2.2 field vulcanized: A joint that is constructed in the field with externally applied heat and pressure to cross-link the joint dielectric.

3.2.3 filled: A joint that consists of an outer shell that is filled with an insulating material to occupy the space around the individual insulated conductor(s).

3.2.4 heat shrink: A joint that consists of a tube or a series of tubes that are applied over the conductor and reduced in diameter over the cable with the use of externally applied heat.

3.2.5 premolded: A joint that is factory molded in the shape that it will take when installed. Installation is performed by sliding the joint over the cable. The use of heat is not a part of the installation procedure.

3.2.6 taped: A joint, that is constructed in the field with the use of one or more tapes that are applied over the cable layers. Heat may or may not be applied as part of the installation procedure.

3.3 Other terms

3.3.1 sectionalizer, sheath or shield: A sectionalizer is used to minimize induced current in the cable metallic sheath/shield by electrically interrupting the semiconducting shield and conducting metallic sheath or shield of two cable lengths that are joined together. Sectionalizers are primarily used on cable systems operating at 60 kV and above as described in ANSI/IEEE Std 575 (Withdrawn) [B1].[7]

4. Service conditions

4.1 Usual service conditions

Cable joints shall be suitable for use under the following service conditions:

a) In air, including exposure to direct sunlight
b) Buried in earth
c) Intermittently or continuously submerged in water at a depth not exceeding 7 m
d) Environmental temperatures within the range of $-30\,^{\circ}$C to $+50\,^{\circ}$C
e) In underground chambers, tunnels, and vaults
f) Approximately horizontal installation of laminated dielectric joints rated 69–500 kV

NOTE—Since neither the production tests nor the design tests included in this specification will insure operation at all "usual" service conditions, it is incumbent upon the manufacturer to utilize appropriate materials and designs that will insure joint functionality at the extremes noted.

[7]ANSI/IEEE Std 575-1984 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://www.global.ihs.com/).

4.2 Unusual service conditions

Conditions other than those listed in 4.1 are considered to be unusual. The manufacturer should be consulted for recommendations.

5. Ratings

5.1 Voltage ratings

The voltage ratings and test levels of cable joints shall be in accordance with Table 1, Table 2, and Table 3.

5.2 Current and temperature ratings

The current and temperature ratings of the cable joint shall be equal to or greater than those of the cable for which it is designed as verified in 7.6, 7.7, 7.11 and the emergency operating temperature test of 7.5.3. For transition joints, the maximum temperature rating is based on the cable with the lower temperature limit.

6. Construction

6.1 Identification

Cable joints shall be permanently and legibly identified with the following information:

a) Company name or logo
b) Part identification
c) Date of manufacture (month and year)

Table 1—Voltage ratings and test levels for extruded dielectric cable joints rated 2.5–35 kV

Voltage rating phase-to-phase, U (kV rms)[a]	Voltage rating phase-to-ground, U_0 (kV rms)[b]	Basic insulation level (BIL) and full wave (kV crest)	AC withstand voltage			DC withstand voltage 15 min (kV)	Minimum partial discharge (corona) voltage level, 1.5 U_0 (kV rms)[c]
			Column A 1 min (kV rms)	Column B 5 min @4.5 U_0 (kV rms)	Column C 5 h @3.5 U_0 (kV rms)		
2.5	1.4	60	9	6	5	30	2
5	2.9	75	18	13	10	35	5
8	4.6	95	23	21	16	45	7
15	8.7	110	35	39	31	70	13
25	14.4	150	52	65	50	100	22
35	20.2	200	69	91	71	125	30

[a]For use with 100% insulation level cable as defined in the applicable AEIC CS5-94 or AEIC CS6-96. To obtain test values for voltage classes that are not listed, use linear interpolation between the next higher and lower listed values and round off to the nearest whole kV.
[b]For grounded systems.
[c]Based on a sensitivity of 3 pC.

Table 2—Voltage ratings and test levels for extruded dielectric cable joints rated 46–500 kV

Voltage rating phase-to-phase, U (kV rms)[a]	Voltage rating phase-to-ground, U_0 (kV rms)[b]	BIL and full wave (kV crest)	AC withstand voltage		DC withstand voltage 15 min (kV)	Minimum partial discharge (corona) voltage level, 1.5 U_0 (kV rms)[c]
			Column A 15 min @3 U_0 (kV rms)	Column B 6 h @2.5 U_0 (kV rms)		
46	26.6	250	80	80[d]	165	40
69	39.8	350	120	100	240	60
115	66.4	550	200	166	300	100
138	79.7	650	240	200	315	120
161	93.0	750	280	232	375	140
230	132.8	1050	400	332	525	200
345	199.2	1300	600	500	650	300
500	288.7	1550	870	725	775	435

[a]For use with 100% insulation level cable as defined in the applicable AEIC CS5-94, AEIC CS6-96 or AEIC CS7-93. To obtain test values for voltage classes that are not listed, use linear interpolation between the next higher and lower listed values and round off to the nearest whole kV.

[b]For grounded systems.

[c]Based on a sensitivity of 3 pC.

[d]Represents 3 times U_0.

Table 3—Voltage ratings and test levels for laminated cable joints

Voltage rating phase-to-phase, U (kV rms)[a]	Voltage rating phase-to-ground, U_0 (kV rms)[b]	BIL and full wave (kV crest)	AC withstand test[c]		DC withstand voltage 15 min (kV)[d]
			Time (h)	Voltage (kV rms)	
2.5	1.4	60	6	8	30
5.0	2.9	75	6	16	38
8.7	5.0	95	6	20	48
15	8.7	110	6	35	55
25	14.4	150	6	58	75
35	20.2	200	6	80	100
46	26.6	250	6	110	125
69	39.8	350	24	100	175
115	66.4	450	24	170	225
120	69.3	550	24	170	275
138	79.7	650	24	200	325
161	93.0	750	24	230	375
230	132.8	1050	24	330	525
345	199.2	1300	24	500	650
500	288.7	1550	24	720	775

[a]For use with 100% insulation level cable as defined in AEIC CS1-90, AEIC CS2-97, AEIC CS3-90, or AEIC CS4-93. To obtain test values for voltage classes that are not listed, use linear interpolation between the next higher and lower listed values and round off to the nearest whole kV.

[b]For grounded systems.

[c]Where this test voltage or test procedure differs from the applicable AEIC specification, the latter shall apply.

[d]Voltages represent 0.5 times the BIL.

Joints that cannot accommodate this information shall be supplied with a label that contains this information. The manufacturer shall also provide a method of securely attaching the label to the outside of the joint after it is assembled in the field unless otherwise specified by the user. In all cases, the identification shall be legible for the life of the joint.

In addition, the following information must be contained on either the joint, the joint components, or the packaging material:

a) "Use before" date, if applicable
b) Maximum phase-to-phase voltage rating
c) Cable insulation diameter range

If the joint consists of a kit that contains a variety of materials manufactured at different times, then the date of manufacture shall be the date that the kit is packaged.

6.2 Shielding

Cable joints shall have a shielding system that is capable of maintaining the outer surface of the joint effectively at ground potential.

6.3 Sheath/shield sectionalizers

Sectionalizers shall be mechanically rugged and resistant to moisture entry. They shall be designed to withstand the voltage stresses applied to them during normal, fault, lightning, and switching surge conditions.

7. Testing

7.1 Production tests

The following production tests shall be performed by the manufacturer of 100% on all premolded and cold-shrink joints produced:

a) Partial discharge (corona) voltage level (see 7.4.1)
b) AC withstand or full-wave impulse withstand voltage (see 7.5.1 and 7.5.3)

7.2 Design tests and testing sequence

Table 4, Table 5, and Table 6 list the sequence of design tests required by this standard.

The design tests listed in Table 4, Table 5, or Table 6 shall be performed on extruded, transition, or laminated dielectric cable joints respectively. All design tests shall be performed on production units (or production materials if the joints are fabricated in the field) to demonstrate compliance of the design with this standard. The results of these tests shall be recorded in the form of a report certifying that a joint design meets the requirements of this standard. The report shall be available from the manufacturer upon request.

Table 4—Design tests and sequence for extruded dielectric cable joints

Design test	Reference	Minimum number of samples required					
		3	3(2)[a]	3(2)[b]	3(1)[c]	3	4
Partial discharge (corona) voltage level	7.4.1	X					
AC withstand voltage	7.5.1	X					
DC withstand voltage	7.5.2	X					
Impulse withstand voltage at 25 °C	7.5.3	X					
Impulse withstand voltage at emergency temperature	7.5.3	X					
Partial discharge (corona) voltage level	7.4.1	X	X	X			
Cyclic aging (in air and water)	7.7.1 7.7.2		X	X			
Partial discharge (corona) voltage level	7.4.1		X	X			
High-voltage time	7.8		X	X			
Sectionalizer test (if applicable)	7.9		X	X			
Short-time current	7.6				X		
AC withstand voltage	7.5.1				X		
Shielding	7.10					X	
Connector thermal and mechanical	7.11						X

[a]For cyclic aging in air, three samples are required for 2.5–35 kV joints according to 7.7.1 and two samples are required for 46–500 kV joints according to 7.7.2.

[b]For cyclic aging in water, three samples are required for 2.5–35 kV joints according to 7.7.1 and two samples are required for 46–500 kV joints according to 7.7.2. (The two 46–500 kV samples in water are not required if the joint design incorporates a solid metal housing that is welded or soldered to a solid cable sheath or pipe.)

[c]One sample is required for 46–500 kV joints.

Table 5—Design tests and sequence for transition joints

Design test	Reference	Minimum number of samples required		
		4(2)[a]	2	4
AC withstand voltage	7.5.1	X		
DC withstand voltage	7.5.2	X		
Impulse withstand voltage at 25 °C	7.5.3	X		
Impulse withstand voltage at emergency temperature	7.5.3	X		
Ionization	7.4.2	X		
Cyclic aging (in air and water)	7.7.2	X		
Ionization	7.4.2	X		
High-voltage time	7.8	X		
Sectionalizer (if applicable)	7.9	X		
Shielding	7.10		X	
Connector thermal and mechanical	7.11			X

[a]Two samples are required in air and two samples are required in water. (The two samples in water are not required if the joint design incorporates a solid metal housing that is welded or soldered to a solid cable sheath or pipe.)

Table 6—Design tests and sequence for laminated dielectric cable joints

Design test	Reference	Minimum number of samples required	
		3(1)[a]	4
AC withstand voltage	7.5.1	X	
DC withstand voltage	7.5.2	X	
Impulse withstand voltage at emergency temperature	7.5.3	X	
Connector thermal and mechanical	7.11		X

[a]Three samples are required for 2.5–35 kV joints and one sample is required for 46–500 kV joints.

7.3 Design test conditions

The following design test conditions shall apply unless otherwise specified:

a) Cable joints shall be properly assembled with actual production components according to the manufacturer's instructions. All parts that are normally grounded shall be connected to the ground of the test circuit.

b) Environmental (ambient air) temperature shall be between 10 °C and 40 °C.

c) All ac voltages shall have a frequency of 60 Hz ± 5% or 50 Hz ± 5%, and a sine wave shape of acceptable commercial standards as defined in IEEE Std 4-1995.

d) Voltages shall be measured in accordance with IEEE Std 4-1995.

e) The cable used in these tests should conform to the applicable AEIC standards. Insulation thickness shall be in accordance with AEIC standards for the 100% insulation level. Unless otherwise stated, the smallest nominal diameter cable for which the cable joint is designed should be used if practical. The exception to this is the short-time current test (see 7.6), in which case the largest nominal conductor for which the cable joint is designed should be used if practical. If testing is performed on cable not conforming to AEIC standards it is incumbent on the manufacturer to insure that the tests are at least as severe on the joint as would be the case on the appropriate AEIC cable. In this case the cable construction and corresponding cable standard must be referenced in the joint test report.

f) If a cable failure occurs during a design test, the failed cable may be reterminated provided that the minimum specified distance between the joint and the termination is met. The test shall be resumed by repeating the step during which the cable failed. If the minimum length cannot be met, the joint on the failed cable or a new joint shall be assembled on a new cable and the design test shall be repeated.

g) If a joint failure occurs during a design test, all qualification tests must be repeated.

7.4 Dielectric integrity tests

7.4.1 Partial discharge (corona) voltage level test

This procedure is used as a production test for premolded and cold shrink joints. It is also part of the design test sequence for all joints intended for use on extruded dielectric cables. The purpose of this test is to verify that the partial discharge (corona) voltage level of the test specimen is not less than the value given in Table 1 or Table 2. The test voltage shall be raised to 20% above the partial discharge voltage level specified in Table 1 or Table 2. If partial discharge exceeds 3 pC, the test voltage shall be lowered to the partial discharge voltage level specified in Table 1 or Table 2 and shall be maintained at this level for at least 3 s but not more than 1 min. If partial discharge readings still exceed 3 pC, the joint design does not meet the requirements of this standard.

7.4.2 Ionization test

This test is applicable only for transition joints. The purpose of this test is to verify that the ionization factor of transition joints remains within the limits specified in Table 7. For joints that contain a laminated cable, the ionization factor is the difference, at 50 Hz or 60 Hz, between the dielectric power factor measured at an average stress in the cable of 4000 V/mm and the dielectric power factor measured at an average stress of 800 V/mm. The measurement voltage is based on the insulation thickness of the laminated cable.

The measurement shall be made at ambient temperature.

For joints on self-contained or pipe-type cables, the ionization factor is defined as the difference, at 60 Hz, between the dielectric power factor measured at 1.2 U_0, and the dielectric power factor measured at 0.125 U_0. U_0, the phase-to-ground voltage, shall be that of the cable with the lower rating.

If the measured value is outside the limits specified in Table 7, the joint design does not meet the requirements of this standard.

This test is not required for joints that employ nonlinear, high dielectric constant or impedance layer materials. However, the manufacturer shall demonstrate that the nonlinear material is stable and will perform effectively over the life of the joint.

7.5 Withstand tests

The purpose of these tests is to verify that the insulation of the test specimen is not defective and will withstand the voltages shown in Table 1, Table 2, and Table 3. Some of the tests are used as both production and design tests.

These tests are applicable for extruded dielectric cable joints, laminated dielectric cable joints, and transition joints. The test voltage shall be applied to the parts of the cable joint that are energized in service.

For transition cable joints, all electrical test values are based on the cable with the lower test requirements.

Table 7—Maximum allowable ionization factor values for transition joints

Joints connecting paper-insulated lead-covered (PILC) cable		Joints connecting self-contained and high-pressure pipe-type cables	
Rated voltage (kV)	**Maximum ionization factor (%)**	**Rated voltage (kV)**	**Maximum ionization factor (%)**
10–20	0.60	≤161	0.10
21–35	0.40	>161	0.05
36–69	0.20		

For pressurized cables, the gas or liquid pressure shall be within the operating limits specified by the appropriate AEIC cable standard.

7.5.1 AC voltage test

This test is applicable for all joint types as a design test and as one of the options for premolded and cold shrink joints in a production test.

The test voltage shall be raised at a rate of 5 ± 3 kV/s to the value specified in Table 1 or Table 2, column A for extruded dielectric cable joints or Table 3 for laminated dielectric cable joints. The cable joint shall withstand the specified test voltage for the time specified in the tables.

For transition cable joints connecting an extruded dielectric cable to a laminated dielectric cable, the test values and durations should be those of Table 3.

7.5.2 DC voltage test

This test is applicable as a design test for all joint types.

The test voltage shall have a negative polarity (the negative terminal is connected to the conductor of the test specimen) and shall be raised to the value specified in Table 1, Table 2, or Table 3. The cable joint shall withstand the specified test voltage for 15 min.

7.5.3 Impulse voltage (BIL) test

This test is applicable for all joint types as a design test and as one of the options for premolded and cold shrink joints in a production test.

The test voltage wave shape shall be as specified in IEEE Std 4-1995, having the BIL specified in Table 1, Table 2, or Table 3 of this standard. The test procedure (including sample conditioning) shall be as specified in IEEE Std 82-1994.

The cable joint shall withstand 10 positive and 10 negative full-wave impulses with a magnitude equal to the BIL value specified in Table 1, Table 2, or Table 3. Tests at emergency operating temperature shall correspond to the impulse temperature requirements outlined in the applicable standards (see Table 8).

For extruded dielectric cable joints, the test shall be performed first with the conductor temperature at ambient temperature, and then again with the conductor temperature at the maximum emergency operating temperature of the cable. The cable emergency operating temperature shall be determined by reference to the applicable standards (see Table 8). The cable manufacturer should be consulted in the case of special-use cables.

For transition joints, the test shall be performed first with the conductor temperature of both cables at ambient temperature, and then again with the cables at elevated temperature. The elevated temperature is based on the maximum emergency operating conductor temperature of the cable with the lower temperature rating. The cable emergency operating temperature shall be determined by reference to the applicable standards (see Table 8). The cable manufacturer should be consulted in the case of special-use cables.

Table 8—Reference cable standards for temperature requirements

Cable type	Standard
1.0–69 kV paper-insulated metallic-sheathed	AEIC CS1-90
69–500 kV high-pressure pipe-type	AEIC CS2-97
8–46 kV low-pressure gas-filled	AEIC CS3-90
15–500 kV self-contained	AEIC CS4-93
5–46 kV cross-linked polyethylene	AEIC CS5-94
5–69 kV ethylene propylene rubber	AEIC CS6-96
69–138 kV cross-linked polyethylene	AEIC CS7-93
600 V–28 kV varnished cloth (VC)	NEMA WC4-1988/ICEA S-65-375

For laminated dielectric cable joints, the test shall be performed only at the maximum emergency operating conductor temperature of the cable. The reference location for all conductor temperature requirements is midway between the end of the joint and the base of the termination. The cable emergency operating temperature shall be determined by reference to the applicable standards (see Table 8). The cable manufacturer should be consulted in the case of special-use cables.

Elevated conductor temperatures are primarily obtained by circulating ac current in the conductor of the cable. There shall be no current in the metallic shields of the cable or joint. In all cases, the test temperature shall be reported in the test report.

When the impulse withstand test is used as a production test, the cable joint shall withstand one full-wave impulse at each polarity with a magnitude equal to the BIL value specified in Table 1, Table 2, or Table 3.

7.6 Short-time current test

The purpose of this test is to verify that the cable joint is capable of withstanding short-time, short-circuit currents. The magnitude shall be equal to the short-circuit rating (in rms symmetrical amperes) of the largest size conductor for which the joint is designed for a duration of 0.17 s. The 50 Hz or 60 Hz current magnitude shall be sufficient to raise the cable conductor temperature from ambient to its rated short-circuit temperature . The current magnitude used for this test shall not exceed 35 kA and may be determined by using ICEA P-32-382, utilizing the formulas given to correct the curves to the appropriate ambient temperature condition.

The current magnitude shall be measured in accordance with IEEE C37.09-1979.

The manufacturer shall verify that the short-circuit test did not cause changes that impede the ability of the joint to operate reliably in service.

7.7 Cyclic aging test for extruded dielectric and transition joints

The purpose of this test is to verify that cyclic loading will not adversely affect the ability of the cable joint to operate in air or submerged in water.

7.7.1 Extruded cable joints rated 2.5–35 kV

The test may be conducted on each joint individually or with two or more joints connected in series.

The cable joints shall be assembled on a cable that has an insulation outside diameter that is at or near the minimum diameter for which the cable joint is designed, and shall be subjected to a continuous ac voltage of three times rated phase-to-ground voltage for 30 days. The test shall be performed on a minimum of three cable joints in air and a minimum of three cable joints in tap water, on the same type and size cable. The same six joints are to be used on all cyclic aging tests. The cable joints in water shall be submerged at a minimum depth of 0.3 m, measured from the top surface of the joints. The water shall not be heated or cooled during this test, but shall be left to follow the load cycling unconstrained.

A minimum length of 2 m of cable is required between joint ends and the base of each termination.

The six joints shall be subjected to 30 load cycles. Each load cycle is defined as a 24 h time span with a current-on period and a current-off period. During the current-on period, sufficient ac current shall be passed through the conductor to achieve a cable conductor temperature within $\pm 5\,^{\circ}C$ of the cable rated emergency operating temperature for a period of at least 6 h. There shall be no current in the cable metallic shield. The cable emergency operating temperature shall be determined by reference to the applicable standards (see Table 8). The cable manufacturer should be consulted in the case of special-use cables.

The reference location for all conductor temperature requirements is midway between the water surface and the base of the end terminations or midway between the joint end and the base of the end terminations for joints tested in air. The temperature at this location shall not be influenced by the joint, water, or end terminations.

The following information shall be recorded in the test report:

a) The maximum temperature of the outside of the joint housings in water
b) The maximum temperature of the outside of the joint housings in air
c) The temperature of the outside surface of the cables in air
d) The cable rated emergency operating temperature used to qualify the joint

During the current-off period, the reference cable conductor temperature should drop to within $5\,^{\circ}C$ of the ambient air temperature. If this condition cannot be met, the test shall be interrupted at the end of the 5th, 10th, 15th, 20th, and 25th cycles. During these interruptions, the voltage, current, and any supplemental heat source shall remain off for a period of 24 h to allow the joints to cool as close to room temperature as possible. The load cycle (current and voltage) and supplemental heat source (if used) shall be resumed at the end of the interruption period. This procedure may be followed even if the temperature condition during the current-off period can be met.

The test specimens shall complete 30 load cycles. The 24 h interruption periods are not considered part of a load cycle.

If, for any reason, the voltage or conductor temperature falls below the specified level at any time during any given load cycle, then that load cycle shall be repeated. Load cycles may be contiguous or there may be periods with no voltage and no current between load cycles to accommodate schedule variations or equipment failures.

7.7.2 Extruded cable joints rated 46–500 kV and transition joints rated 2.5–500 kV

The test may be conducted on each joint individually or with two or more joints connected in series. The conductors of multiconductor joints shall be connected in series.

The cable joints shall be assembled on cables that have an insulation outside diameter that is at or near the minimum diameter for which the cable joint is designed. Sheath/shield sectionalizers shall be incorporated if they are part of the joint design. They shall remain shorted until the tests in 7.9 are performed.

Testing shall be performed on four cable joints. The same four joints are to be used for all cyclic aging tests. Multiconductor joints in a common housing are considered one joint. Two joints are suspended in air and two are submerged in tap water to a depth of 1 m. The two samples in water are not required if the joint design incorporates a solid metal housing that is welded or soldered to a solid cable sheath or pipe.

If conduit is used for the in-water portion of this test it shall be made of any appropriate material and shall have an inside diameter that is 50–80 mm larger than the outside diameter of the joint being tested. The conduit (or enclosure) shall be longitudinally centered on the joints and shall extend a minimum of 300 mm beyond each joint end. A minimum length of 2 m of cable is required between the conduit and the base of each end termination for joints tested in water or between the joint ends and the base of each termination for joints tested in air. A vertical tube having a minimum inside diameter of 50 mm shall be attached to the conduit. It shall be of sufficient length to provide the specimen with a head of tap water measuring a minimum of 1 m from the top surface of the joint. The water shall not be heated or cooled during this test, but shall be left to follow the load cycling unconstrained.

The four joints shall be subjected to 30 load cycles. Each load cycle is defined as a 24 h time span with a current-on period and a current-off period. During the current-on period, sufficient ac current shall be passed through the cable conductor to achieve a conductor temperature within $\pm 5\,^\circ$C of its rated emergency operating temperature for a period of at least 6 h. For transition joints the emergency operating temperature of the cable with the lower rating shall be used. The cable emergency operating temperature shall be determined by reference to the applicable standards (see Table 8). The cable manufacturer should be consulted in the case of special-use cables.

Two times the rated phase to ground ac voltage shall be applied continuously for the 30 cycles. For transition joints, two times the rated phase to ground ac voltage of the cable with the lower rating shall be used. There shall be no current in the cable metallic shield.

The reference location for all conductor temperature requirements is midway between the end of the conduit and the base of the end terminations for joints tested in water or midway between the joint ends and the base of the end terminations for joints tested in air. For transition joints this measurement is made on the cable with the lower temperature rating. The temperature at this location shall not be influenced by the joint, water-filled conduit, or end terminations.

The following information shall be recorded in the test report:

a) The maximum temperature of the outside of the joint housings in water
b) The maximum temperature of the outside of the joint housings in air
c) The temperature of the outside surface of the cables in air
d) The cable rated emergency operating temperature used to qualify the joint

During the current-off period, the reference cable conductor temperature should drop to within 5 °C of the ambient air temperature. If this condition cannot be met, the test shall be interrupted at the end of the 5th, 10th, 15th, 20th, and 25th cycles. During these interruptions, the voltage and current shall remain off for a period of at least 24 h to allow the joints to cool as close to room temperature as possible. The load cycle (current and voltage) shall be resumed at the end of the interruption period. This procedure may be followed even if the temperature requirement during the current-off period can be met.

The test specimen shall complete 30 load cycles. The 24 h interruption periods are not considered part of a load cycle.

If, for any reason, the voltage or conductor temperature falls below the specified level at any time during any given load cycle, then that load cycle shall be repeated. Load cycles may be contiguous or there may be periods with no voltage and no current between load cycles to accommodate schedule variations or equipment failures.

For transition joints the ionization factor shall be measured as specified in 7.4.2 at the beginning of the test period and at the end of the load cycle test (the completion of 30 cycles). The ionization factor shall be in accordance with Table 7.

For transition joints the internal pressure of the pressurized and laminated dielectric cable shall be maintained at normal operating pressure throughout this test, except for solid-type laminated dielectric cables, which shall have a maximum pressure during the test of 103 kPa (gauge).

7.8 High-voltage time test

The purpose of this test is to verify the electrical integrity of extruded dielectric and transition joints after they are subjected to the cyclic aging tests of 7.7. Table 4 and Table 5 specify the design test sequence. Test voltage is applied as follows:

For extruded dielectric cable joints rated 2.5–35 kV:

— Test voltage specified in Table 1, column C for 5 h followed by:

— Test voltage specified in Table 1, column B for 5 min

For extruded dielectric cable joints rated 46–500 kV:

— Test voltage specified in Table 2, column B for 6 h

For transition joints rated 2.5–500 kV:

— Test voltage and time as specified in the ac withstand voltage column of Table 3

All joints subjected to this test shall be completely submerged in ambient temperature tap water. The submersion depth is a minimum of 0.3 m for 2.5–35 kV extruded dielectric cable joints and a minimum of 1 m for 46–500 kV extruded dielectric cable joints and all transition joints. These submersion depths correspond to the submersion depths required during the load cycle tests for each joint construction. They are measured from the top surface of the joint.

The joint shall be submerged for at least 1 h before the test voltage is applied. Samples previously tested in a water-filled conduit may be left in the conduit. Samples previously tested in air shall be submerged in tap water using any convenient method.

7.9 Sectionalizer tests

Cable joints with sectionalizers shall be tested in accordance with the following procedures. All joints subjected to this test shall be completely submerged in ambient temperature tap water. The minimum submersion depth shall be 0.3 m for extruded cable joints rated 2.5–35 kV and 1 m for all other joints. This depth corresponds to the submersion depth required during the load cycle test, subclauses 7.7.1 and 7.7.2, for each joint construction and is measured from the top surface of the joint.

The joint shall be submerged for at least 1 h before the test voltage is applied. Samples previously tested in water may remain there. Samples previously tested in air shall be submerged in tap water using any convenient method.

7.9.1 Sectionalizer ac withstand tests

A voltage of 20 kV ac shall be applied across each sectionalizer for a minimum of 1 min. During this test the water should be grounded for safety. The sectionalizer shall then be shorted and 20 kV ac shall be applied between the sectionalizer and the grounded water for a minimum of 1 min. The sectionalizer shall withstand both tests without arcing across or to ground.

7.9.2 Sectionalizer impulse withstand tests

The impulse test voltage shall be a $1.2 \times 50\,\mu s$ wave that meets the requirements of IEEE Std 4-1995. Ten 60 kV crest, positive impulses followed by ten 60 kV crest, negative impulses shall be applied across the sectionalizer. The sectionalizer shall then be shortened and ten 30 kV crest, positive impulses followed by ten 30 kV crest, negative impulses shall be applied between the sectionalizer leads (cable shields) and the grounded water. The sectionalizers are considered satisfactory if the impulse voltage is withstood without any physical damage to the joint, cable, or sectionalizer.

7.10 Shielding tests

The purpose of this test is to verify that the cable joint insulation shield will maintain the outer surface effectively at ground potential under normal operating conditions, and initiate fault current arcing if the cable joint insulation system should fail.

The insulation shield of all joint types shall meet the resistivity stability requirement of IEEE Std 592-1990. All joints with exposed semiconducting shields for use on extruded dielectric cables rated 15–35 kV shall meet the short-circuit requirements of IEEE Std 592-1990.

7.11 Connector thermal and mechanical tests

The purpose of these tests is to verify that connectors used to join two aluminium conductors or an aluminium conductor to a copper conductor meet all applicable tests given in ANSI C119.4-1991. The manufacturer should follow a similar test protocol to verify that connectors used between copper conductors will perform reliably in service.

NOTE—the Class A heat cycle test and the Class 2 partial tension test from ANSI C119.4-1991 should be used.

Annex A

(informative)

Bibliography

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